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PROGRESS REPORT

TO

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

ON

CONTRACT NO. NASr-82

CONSTRUCTION OF A 61-INCH LUNAR AND PLANETARY TELESCOPE

by

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ON
CONSTRUCTION OF A 61-INCH LUNAR AND PLANETARY TELESCOPE

Gerard P. Kuiper

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Two progress reports have been issued, dated March 1 and October 1, 1964 respectively. Reference is made to these for the earlier history of the program.

I. The Optics

Mr. Robert L. Waland, Chief Optician, and his two aids, have essentially completed the optics of the telescope. The main mirror as well as the F/13.5 Cassegrain secondary have been crated for shipment to California where they will be aluminized. Some minor polishing is still needed on the F/45 secondary. The secondaries were polished to their theoretical figure with the aid of a 50-inch spherical mirror loaned to us by Kitt Peak National Observatory. Their final checking and possible retouching must await their installation in the assembled telescope at the Catalina Station, with stars used in these final tests. Mr. Waland has stated that the secondary mirrors are both very close to their intended theoretical figures. (Final tests can not be made in the optical shop; they would require the use of a 60-inch optically flat mirror, which was not available. Furthermore, any residual disturbances introduced by the support systems can be discovered and be eliminated by final retouching, only upon installation.)

The primary mirror is truly a work of art and we are extremely pleased with the precision Mr. Waland has obtained. Various tests made over the past two months have indicated its figure to approximate the theoretical paraboloid by $1/40$ to $1/20$ of a wavelength. Once this precision is obtained it is exceedingly difficult to be sure of the precise figure of the mirror because daily temperature changes in the

optical shop of the order of 1-2 degrees are sufficient to cause the mirror to vary by this amount. Mr. Waland has endeavored to achieve a surface that is a figure of revolution within the full precision of his tests, which is well below $1/40$ of a wavelength (0.5 millionths of an inch). This he has achieved. The last controls were made at the center of curvature with an effective F ratio of 8 and some minor ridges were detected that had escaped in the earlier tests carried out at F/4. These small ridges were successfully removed (the optician used his thumb as an optical tool), and an exceedingly good optical surface has resulted which produces no detectable light outside an image diameter of $1/3$ arc seconds. Most of the light is concentrated in the diffraction disk (0.08 arc seconds) and the optics will in practice give images not over 0.1 arc seconds when the atmospheric conditions allow this.

The clear aperture of the telescope is 60.8 inches. Since we have also a 60-inch metal mirror for IR work at the Catalina Station, we avoid confusion by calling the NASA telescope the 61-inch.

In October 1964, we had the benefit of consultations with the well-known French optician Jean Texereau, who had made very remarkable improvements to the optics of the 82-inch McDonald telescope. It was concluded that the ultimate in the resolution of the 61-inch NASA telescope will require its tube to be closed and covered by a plane optical plate located in front which could be so located as to support at the same time the 7-inch secondary mirror. This arrangement would incidentally avoid the use of a supporting web for the secondary and thus eliminate the diffraction cross distorting all stellar images of ordinary reflectors. The comparatively excellent results we have obtained in lunar photography with the 40-inch Yerkes refractor in a climate that is really not very good, are apparently due to the absence of turbulence within the telescope tube, which is so prominent in reflectors. We have experienced, for example, a serious deterioration of image quality in the

Kitt Peak 84-inch telescope as a result of air pockets and turbulence immediately above the mirror, caused by the heating of cold outside air descending into the tube, by the massive pyrex disk. This trouble can be avoided only by enclosing the entire tube which makes the interior essentially isothermal.

Because the purpose of the NASA telescope is to reach the ultimate in photographic resolution (about 0.1 arc seconds) I am now convinced that we should proceed this way. At least one-half year of difficult optical work will be required to polish this large plane parallel plate, because we wish to keep its thickness to 1 or $1\frac{1}{4}$ inch. A formal request for its production under the present contract will be forwarded soon. We anticipate that with such a plate on most nights the image resolution on the moon and planets will be improved two or three fold. We see no reason why the telescope then should on 20-40 nights each year not give a resolution of $1/10$ arc seconds, this number then being restricted only by outside atmospheric conditions. This would revolutionize lunar and planetary astronomy, since resolution on a planetary disk depends on area more than linear dimension; i.e. a gain of the order of 10 x would be achieved over the best available photography.

The completion of a telescope designed to reach the limit of its potential will involve much study, experimentation, and time. A no-cost extension of the contract for one year was requested in my memorandum of January 12, 1965. Actually, a two year extension would have been better, because I do not think that we shall have exhausted the possibilities by April 15, 1966.

II. Mounting

As stated in the October report, the contract for the telescope mounting was awarded to the Western Gear Corporation of Lynwood, California. They fabricated the components as outlined on page 2, section 3 of the October 1 report. The telescope mounting was originally scheduled for delivery the first part of January 1965; however, some design changes and modifications were introduced and the delivery date was moved to the first part of February 1965. As the telescope was being

disassembled for shipment on February 7, 1965, an accident occurred that was reported to NASA in my letter of February 9, 1965, of which a copy is appended.

The primary mirror flotation system, consisting of some 1178 parts, was fabricated in our university machine shop and installed on January 20, 1965, taken there personally by truck by our Design Engineer, Mr. Sam Case. A dummy mirror of concrete was produced and installed in the cell for proper balance.

The telescope and dummy mirror were erected at the Western Gear Plant late January and balanced, so that the loads and deflection on the shafts and yoke could be determined. The drives were installed and the entire system was checked and found to be within the design specifications. The precision of the right ascension gear was evaluated in the gear testing laboratory and found to be within $0''.5$ (seconds of arc) when three teeth were engaged as called for in the specifications.

During the final disassembly of the telescope on February 7, 1965, the company workmen had removed the primary mirror cell from the bottom of the telescope tube. The cell, together with the dummy mirror and flotation system, weighs about 7000 pounds and the removal of this weight made the tube top heavy by about 600 pounds or 7800 foot-pounds. The workmen had secured the top of the tube with a safety chain and were in the process of turning the telescope tube toward the south end of the yoke, in order to have enough room for their overhead crane to pass and lift the tube from the yoke. At an angle of approximately 45° the chain hoist and the safety chain both broke and the tube came down on top of the 5 foot diameter right-ascension worm gear. Four or five teeth were flattened and for most of the remaining part of the gear the distortions were up to 20 arc seconds. The gear was therefore unacceptable.

Western Gear Corporation thoroughly checked the rest of the telescope, i.e. shafts, bearings, drive systems, etc., and found no evidence of damage.

The Vice-President of the company visited this Laboratory on February 8 and this was followed by a visit to the company on February 10 by Dr. G. P. Kuiper and Mr. Sam Case, who thoroughly studied the damage and the steps to be taken for a fully satisfactory telescope. It was agreed that the company would fabricate a new 5-foot worm gear and re-erect and test the complete telescope in their plant at no additional cost to the University and the Contract.

The opportunity had now presented itself for the LPL staff to ask a number of critical questions on the remainder of the mounting in an effort to ensure ultimate top quality performance, absence of flexure, etc. The points of issue were all mechanical and could be dealt with more fully and clearly on the completed instrument; also, the need for a third cage carrying the heavy optical plate had meanwhile emerged. Out of this analysis developed a plan for strengthening the lower part of the tube and for improving the declination bearing system. These improvements might not have been essential in the original design, but with the new requirements for a heavy third cage, housing the plane-parallel optical plate and third secondary, the added strength of the tube and bearings were called for. I believe that the gain in the telescope design may be regarded as having largely offset the scientific loss resulting from the 3 month delay in the completion date of the telescope. We have now every reasonable assurance that the telescope will be fully up to standard. The new delivery for the mounting and worm gear is April 27, 1965.

III. Building and Dome

The 43-foot dome to house the 61-inch telescope was essentially completed in March, 1965. The painting of the outside remained to be done, awaiting warmer weather and is scheduled to be completed by mid-April, 1965. The inside office and work areas have pleasant light blue colors. The color pattern was adapted from that chosen by the U. S. Naval Observatory at Flagstaff, Arizona. The dome and hydraulic hoist function very well. Steps are being taken to install the connecting

water and sewer systems.

Pictures of the dome are appended. We hope that by May 15 the telescope will be in part-time operation on programs involving lunar and planetary photography, IR spectroscopy 1 - 24 μ , and visual observation. A photographic spectroscopy program will be initiated later. As stated above, tests for further improvements are to be continued for at least 1-2 years.